Multi-site Monitoring of Heat Stresses and Micrometeorological Conditions in the Rice Plants Communities under Various Climates -The Micrometeorological Measurements System for a Common Measure of the Paddy Environments -

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Abstract: Rice yield can be reduced substantially when the crop is exposed to excessive heat, which will likely occur more frequently under future climates, but the magnitudes of yield losses under open-field conditions are still difficult to predict, despite many efforts being conducted to determine temperature response in the closed environments. To better understand the occurrence of heat stress under field conditions, we need thermal conditions of rice canopy under heat conditions, which can be very much different depending on other environmental factors, but taking correct measurements of canopy micrometeorology needs careful considerations. In this study, we will distribute a simple but well-designed system for measuring thermal environments of the canopy to different rice growing regions covering continental and coastal climates in low and mid latitude regions. With them, we attempt to establish a monitoring network of canopy thermal environments in the paddy fields that will help to bridge gaps between chamber and open-field and to better assess potential impacts of climate change on rice production.
Keywords: Canopy heat budget, Climate change, Micrometeorology, Multi-lateral research network, Rice

1. Introduction

The Intergovernmental Panel of Climate Change has reviewed a number of simulation studies attempting to determine the effect of climate change on crop yields in their 4th assessment report and summarized that negative effects of rising temperature may appear if the temperature rises by 3°C in mid-to-high latitude regions and just by 1°C in low latitude regions [1]. As a result of global warming, extreme heat events will likely occur more frequently. Excessive heat, even if it is a short spell, can reduce yields of crops due to failure of reproductive growth, but the effects of such events on crop growth and yield have not been well accounted for by many crop models, so that we cannot assess the negative effect of rising temperature properly: This is one of the major uncertainties about the future yield prediction.

Rice, the staple food for about 3 billion people is not an exception. Although rice is highly adaptive to a range of environments, previous chamber experiments have shown that rice is also highly susceptible to heat [2,3]. According to their studies, flowering is the most sensitive stage and heat-induced spikelet sterility (HISS) is the major reason for the yield loss. The threshold temperature for HISS was around 35 °C at the time of flowering, which has already been reported even under current climates. The yield loss due to HISS, however, has not been well documented in the rice industry. Filling the gap between chambers and open-field is an important task for researchers working in the field of crop physiology and agricultural micrometeorology.

One reason for the seemingly contradictory fact may be the fact that thermal conditions of the rice canopy can be different from air temperatures. For instance, Matsui et al [4] have demonstrated that the panicle temperatures can be substantially lower than air temperatures by as much as 6-7 °C under hot and dry conditions in the Riverina Region, New South Wales, a major rice production area in Australia, while panicle-air temperature difference was only around 0.5 °C in Jiangsu Province, China [5]. This suggests that the impacts of rising temperature can be moderated substantially by the factors that affect canopy heat balance.

The air-canopy temperature difference depends on various meteorological conditions such as solar radiation, wind speed, relative humidity and hydrological conditions of the field. Other important factors that influence the thermal conditions of the canopy and panicles include physiological and morphological properties of the rice varieties. For a proper assessment of the vulnerability of rice production to any environmental change, we need micrometeorological data in the open paddy field under variable climatic and management. Unfortunately, however, very limited information is available on the canopy and air temperature relationship: This limits our ability to assess risks of heat injuries due to excessive heat.

For this reason, we have initiated a research project aiming to develop a network of monitoring paddy micrometeorological conditions and heat damage under the "Multilateral Research Exchange Project for Securing Food and Agriculture", funded by Agriculture, Forestry and Fisheries Research Council, MAFF. We attempt to establish a monitoring network of canopy thermal environments in the paddy fields that will help to bridge gaps between chamber and open-field and to better assess potential impacts of climate change on rice production. In this paper, we introduce outline of the activities which will take place under this research network.

2. Outline of the micrometeorological measurements system

There are some difficulties for this monitoring system: Micrometeorological measurements need careful setting of the sensors, without which reliable field weather data are difficult to obtain. Ideally, continuous measurements of organ temperatures will provide us with important information, but they require elaborate measurement systems and skilled work, which does not suit the multi-site monitoring. For this purpose, we have developed a simple system to monitor temperature and humidity profiles of the rice canopy, which can be easily handled by agronomists and crop physiologists.

The system is equipped with a force-ventilated radiation shield and measures profiles of the air temperature and humidity (Fig.1). So far, naturally ventilated radiation shields have been often used because of the difficulty of electric power supply. However, natural ventilation may cause the error since the shields heated by the solar radiation emits long-wave radiation which will result in erratic rise in temperature of the sensor. The magnitude of rise depends on the differences of radiation and wind condition between sites, making the multi-site monitoring difficult. On the other hand, in the case of using a force-ventilated radiation shield, it is needed to wire power cables for supplying electricity to a ventilator far in the paddy field. To break these limitations, we developed a stand-alone

Fig. 1. Prototype of the temperature and humidity profile measurement system equipped with a force-ventilated radiation shield and a solar panel.

force-ventilated system utilizing a solar cell powered ventilator equipped with rechargeable batteries (Solar Vent MPV, ICP Solar Technologies Inc.) and a power control circuit developed by NIAES. In the daytime with sunlight, the ventilating speed around the sensor will be maintained around 3 m/s, minimizing the error by cooling down both the sensor and the shields. In the nighttime, as it is not necessary to cool down, the circuit automatically lowers the ventilating speed roughly by half which is enough to sample the air inside the canopy, extending the operating duration under no sunlight. With the power control circuit, the ventilator can work continuously for two consecutive cloudy or rainy days with no power generation and nights if the batteries are fully charged. A small temperature and humidity sensor with integrated logging function (Osaka Micro Computer Inc. LS350-TH) is also self-powered with a lithium battery and completely housed inside the ventilated radiation shield. The system is light-weight and can be settled at any desired height in rice canopy using an adjustable tripod. These features ensure that anyone can easily handle the system and conduct accurate measurement in the field.

3. Target area

In this study, we will initially target several rice growing regions in the world (Fig. 2). We have selected these sites to cover continental and coastal climates in low and mid latitude regions. Later on, we hope to increase monitoring sites so as to cover wider climate conditions, different paddy ecosystems and a range of farming scales.

At each site, field trials will be conducted using site's standard cultivar and conventional management. Additionally, one or more comparative treatments will be imposed on the crop: the treatment can be cultivar, management (water or fertilizer) depending on the region and/or participants' interest. Measurements can be repeated for both wet and dry seasons.

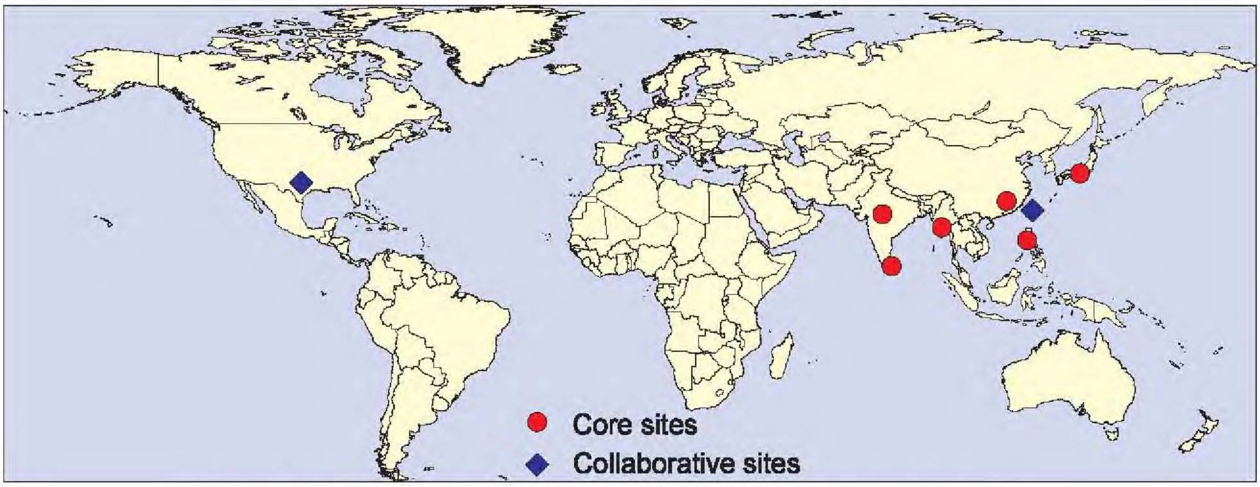

Fig. 2. Target regions of the multi-site monitoring at the initial stage of the project.

4. Implication of this network

This network is aimed at filling the knowledge gaps between chamber and open field experiments in the climate change impact studies. The rice canopy micro-meteorological data obtained with a common methodology across sites of different climate zones together with crop data will improve our quantitative understandings of climate change impacts on rice communities. By analyzing the relationship between above-canopy and inside-canopy thermal conditions at each site and across sites, susceptibility to climate change of the regions can be characterized. We will also compare them with the on-station weather data and/or with the near-by weather station data. The workshop, micro-meteorological measurements and data analysis will be also be a good opportunity for improving research capacity in the area of agricultural meteorology, which is highly important in climate change impacts and adaptation studies. These activities will help to detect signs of climate change impacts in various rice growing regions in the world, which information is shared by the international scientific community.

Acknowledgement

We wish to thank Agriculture, Forestry and Fisheries Research Council, MAFF, for giving us an opportunity to set up a world-wide network under the "Multilateral Research Exchange Project for Securing Food and Agriculture".

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